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12.—A Contribution to the Petrology of the Yandanooka Group

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The Yandanooka Group is a thick (approximately 30,000 ft.) sedimentary sequence in the Yandanooka area, west of the Darling Fault Zone in Western Australia. Formations in the group, from the base upward, are: Arrowsmith Sandstone, Arrino Siltstone, Beaconsfield Conglomerate, Enokurra Sandstone and Mt. Scratch Siltstone. They represent deposits ranging from probable continental facies, through littoral to somewhat deeper water facies. Lithologic types include conglomerates, feldspathic quartz sandstones, arkoses, lithic sandstones, siltstones and shales. All formations except the Enokurra Sandstone contain a notable proportion of volcanic fragments. Much of the volcanic material was clearly derived from erosion of extrusive rocks, but some of the volcanic material in the Mt. Scratch Siltstone appears to be tuffaceous, and probably represents volcanism that occurred during sedimentation. Conglomerates in the group contain numerous spilitic pebbles and cobbles.

The high proportion of labile grains (such as feldspar, and granitic and volcanic fragments) indicates the absence of effective chemical weathering. This was probably a result of rapid erosion and transport from a hinterland of strong relief. The sediments appear to have been laid down in a basin that subsided considerably during deposition.

Introduction

The Yandanooka Group is a thick sequence of unfossiliferous sedimentary rocks bounded by Precambrian rocks of the north-north-westerly trending Mullingarra Inlier to the west, and the Darling Fault Zone to the east (see Fig. 1). Formations in the Yandanooka Group have an aggregate thickness of about 30,000 feet, and have been formally defined by Playford and Willmott in McWhae, Playford, Lindner, Glenister and Balme (1958). Other reference to these rocks has been made by Campbell (1910), Woolnough and Somerville (1924), Baker (1951), Johnson, de la Hunty, and Gleeson (1954) and Glover (1958*a*). The age of the rocks is doubtful, and is considered by McWhae *et al.* to be late Precambrian or early Palaeozoic.

The sequence according to McWhae *et al.* may be summarized as follows:

	ft.
5—Mt. Scratch Siltstone	25,000-30,000
4—Enokurra Sandstone	680
3—Beaconsfield Conglomerate	130
2—Arrino Siltstone	1,670
1—Arrowsmith Sandstone	1,100

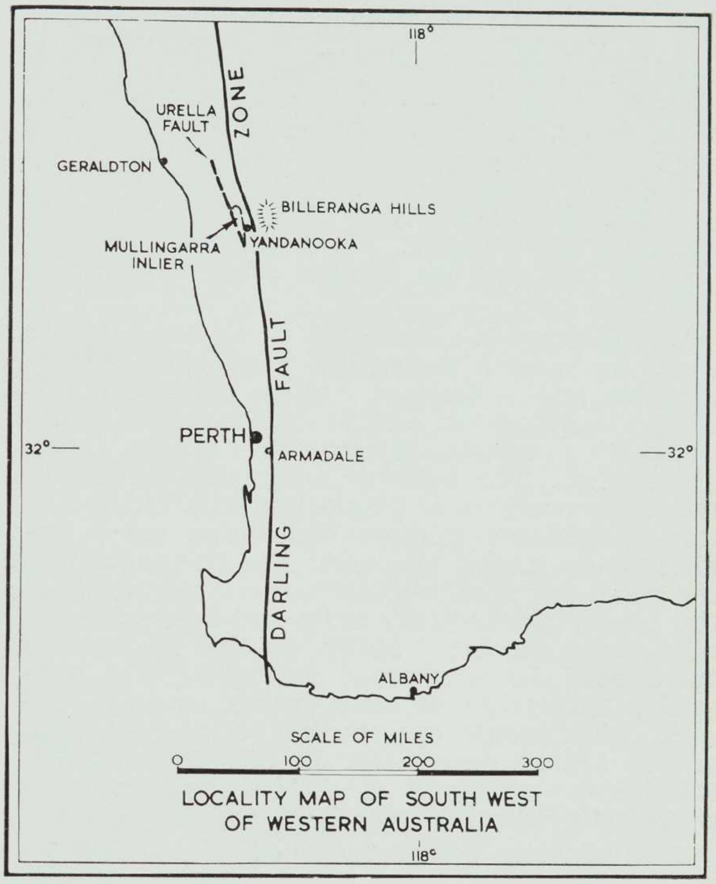

Fig. 1.—Locality map showing the Yandanooka area.

With the exception of Mt. Scratch Siltstone and Enokurra Sandstone, thicknesses are quoted from type sections of formations. Incomplete thicknesses are represented at the type sections of Mt. Scratch Siltstone and Enokurra Sandstone.

In the present study, 36 specimens from the Yandanooka Group were examined under the petrologic microscope and three specimens previously described by Simpson and Glauert (in Campbell 1910) were re-examined. A description of the Beaconsfield Conglomerate, based on the study of 14 thin sections, has already been published (Glover 1958*a*), but results are incorporated here. Specimens whose numbers are prefixed by the letters Pf were made available by West Australian Petroleum Pty., Ltd.: other specimens are those of the Geology Department of the University of Western Australia.

No detailed maps showing the distribution of the Yandanooka Group have so far been published, and further work may result in finer

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subdivision of this thick sequence and in the collection of rock types not described here. Moreover, the group has not been drilled (apart from shallow water bores) and no subsurface samples are available. Nevertheless, the 53 specimens studied are probably sufficiently representative to justify a preliminary discussion of the petrology.

Arrowsmith Sandstone

Petrography

The Arrowsmith Sandstone is a uniform sequence of well-bedded, medium- to coarse-grained sandstone that contains abundant feldspar and lithic fragments. All specimens examined in the laboratory are arkoses, according to the tabular sandstone classification of Pettijohn (1957, p. 291). The mineralogy and texture of specimen Pf2 is described below in some detail, and is illustrated in Fig. 3A. The rock is a medium-grained arkose made up mainly of sub-angular to well-rounded quartz and feldspar grains, and lithic fragments that are generally angular. Its coefficient of sorting (So) is 1.39 and the median grain diameter is 0.33 mm.

The feldspar is plagioclase (sodic oligoclase to sodic andesine), microcline, microcline microperthite and orthoclase. Lithic fragments include volcanic rock, sericite-quartz schist, many composite quartzo-feldspathic grains, and myrmekite. The volcanic fragments consist of micro-phenocrysts of plagioclase in a red-brown iron-stained groundmass containing some unaltered black iron minerals: the fragments are too small for precise classification, but much of the plagioclase is fairly sodic and appears to be oligoclase-andesine. Many of the grains are surrounded by a narrow rim of fibrous, pale green, authigenic chlorite which cements the rock. Authigenic outgrowths on some of the quartz grains also assist in the cementation. Despite the presence of volcanic material, no vitroclastic textures have been recognized.

Approximate composition of the rock by volume is:

	Per cent
Quartz	40
Feldspar	27
Volcanic fragments	13
Other lithic fragments	13
Cement	6
Other minerals	1

Heavy minerals were separated in bromoform from the fraction with grain diameters between 0.66 mm and 0.124 mm, and compose about 15 per cent. of that fraction. Volcanic fragments (generally angular) and rounded black opaque grains (ilmenite with a little magnetite) are abundant. Some of the volcanic fragments are attracted by ordinary bar magnet, and at least part of their contained iron minerals is therefore magnetite. Pale pink, slightly magnetic, angular, strongly etched garnet is common, and much of it is partly altered, apparently to a mixture of feldspar and white mica. Clear garnet grains have a refractive index close to 1.810 and they are probably almandine. Other common heavy minerals are sphene and zircon. The sphene is cloudy and angular, and there are three varieties of zircon: colourless to pale brown, very well-rounded grains; colourless to pale brown, zoned, well-rounded grains; and rare lilac euhedra. Rare heavy minerals include rounded apatite, brown and black, rounded and angular tourmaline, and rounded rutile.

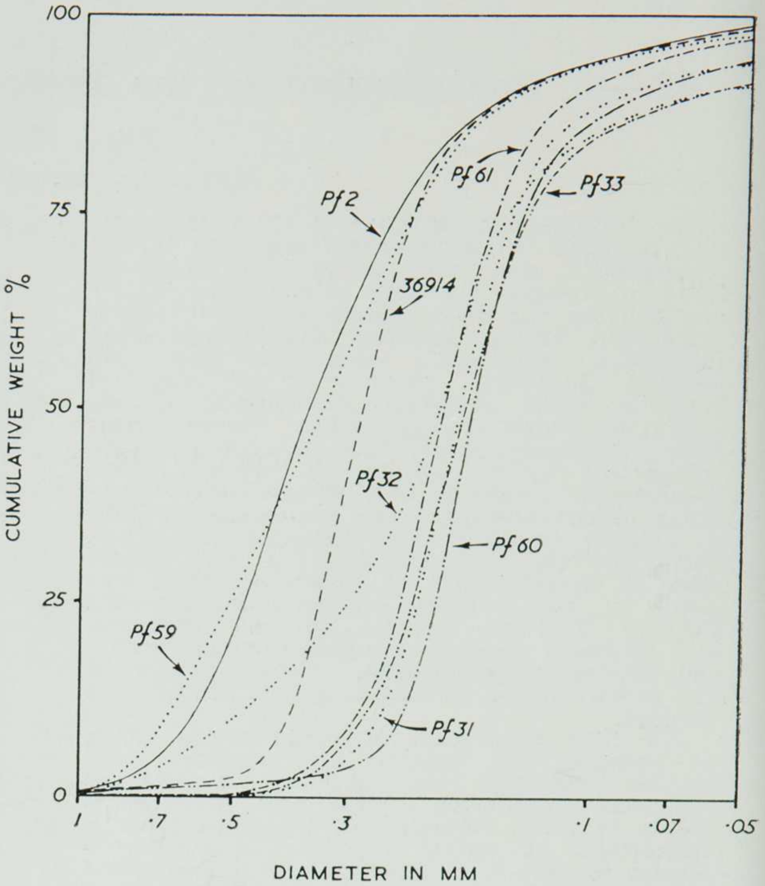


Fig. 2.—Cumulative weight per cent curves of 8 specimens of Arrowsmith Sandstone. The abscissae are on a logarithmic scale. Note the high degree of sorting of most specimens.

Eight specimens of Arrowsmith Sandstone (36914, Pf 2, Pf 31, Pf 32, Pf 33, Pf 59, Pf 60, Pf 61) were disaggregated by maceration in water, and after mechanical analysis, cumulative weight per cent curves were constructed (Fig. 2). The curves do not precisely represent the original sorting of the rock, which has changed after deposition by secondary enlargement of some quartz grains and transformation of cement to fibrous chlorite. Nevertheless, the curves probably indicate fairly closely the original sorting. The coefficient of sorting ranges between 1.18 and 1.50 indicating a well-sorted sediment (Trask 1932) and falls within the range of sorting of most near-shore marine sediments of sand grade, according to Hough (1942).

The roundness of the quartz grains was compared with the standards set forth by Krumbein (1941). No precise grain counts were attempted, as an unknown number of grains have an induced angularity due to authigenic growth, but some significant features are evident. Quartz grains smaller than 0.124 mm in diameter are practically all angular (.2 to .3), some grains in the 0.124-0.246 mm range are slightly rounded (.4 to .5), many grains in the

0.246-0.495 mm range are moderately well-rounded (.5 to .6) and most coarser grains are well-rounded (.6 to .8). It would appear from the investigations of Kuenen (1959) that the grains must have been modelled by either wind or surf, and the earlier work of Twenhofel (1945) suggests that wind traction may have been a factor in rounding the grains of less than 0.495 mm diameter. The grains seem to have been rounded in one cycle, for no earlier formation capable of yielding rounded grains has so far been recognized in the area.

Environment of Deposition

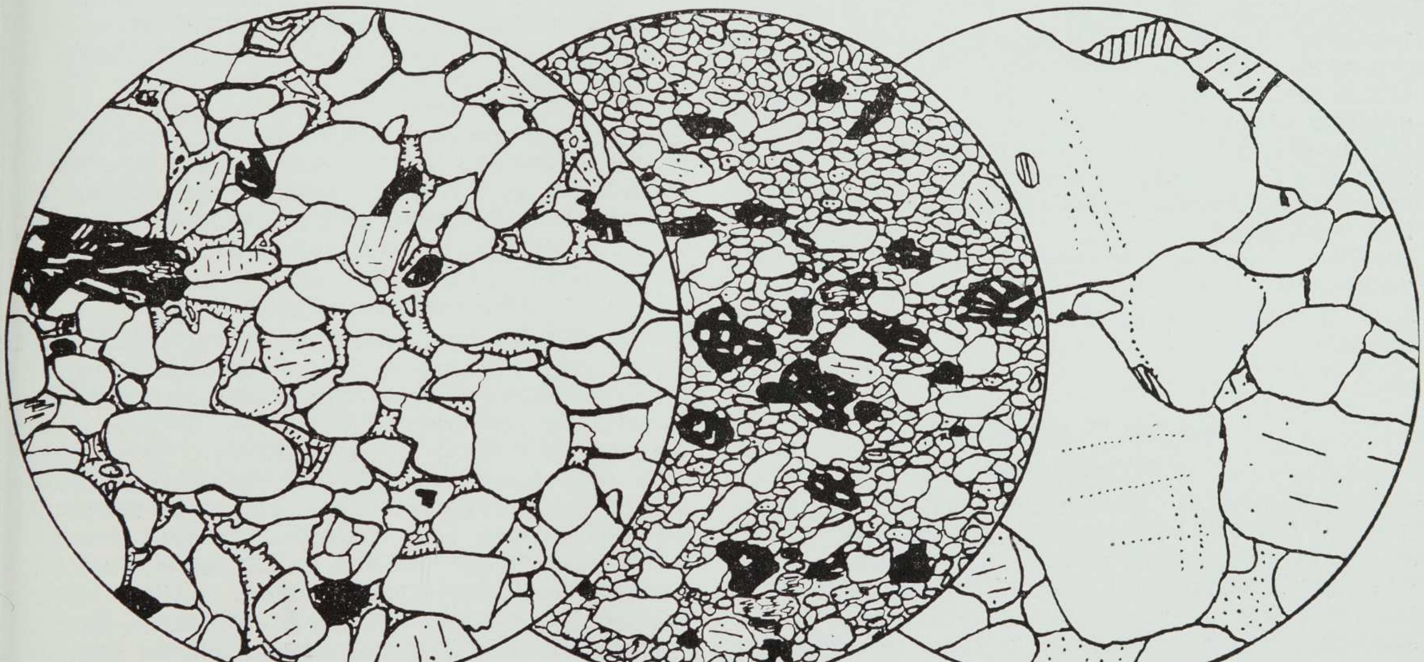
The parameters discussed above are consistent with a near-shore, marine environment. The abundant labile grains, such as feldspar and volcanic fragments, indicate the absence of effective chemical weathering. This may have resulted from rigorous climatic conditions, but other factors discussed at the end of the paper suggest that climate was not the main influence. It is more likely that dominantly mechanical disintegration, and rapid transport to the site of deposition, prevented soil formation, with its attendant chemical transformation of unstable grains. The Arrowsmith Sandstone was derived from a granitic, meta-sedimentary and volcanic terrain that was therefore probably fairly rugged, and it appears to have been deposited near the strand line of a subsiding basin.

Arrino Siltstone

Petrography

The Arrino Siltstone is a uniform sequence of poorly bedded, dark, reddish brown, micaceous siltstone that rests conformably on the Arrowsmith Sandstone. Four specimens (Pf 3, Pf 4, 36915, 36916) were examined microscopically. The rocks are sandy siltstones, with quartz content ranging from 37-73 per cent and all contain numerous lithic fragments which are generally concentrated in the coarser fractions. The content of volcanic fragments ranges from 7-15 per cent and that of other lithic fragments from 10-43 per cent. The volcanic fragments consist of micro-phenocrysts of plagioclase in a red-brown, iron-stained matrix that also contains abundant black magnetite: the other fragments include garnet granulite, muscovite-biotite-quartz schist, chlorite-quartz schist, (?) chert, epidote-quartz rock, and other composite grains commonly containing quartz, carbonate and chlorite. Feldspar (plagioclase and microcline) comprises up to 5 per cent of the siltstone. Both sand and silt grains are generally angular, and are commonly cemented by pale green, locally fibrous, chloritic cement that constitutes from 3-8 per cent of the rock. In places, the cement is stained red-brown. Specimen 36916 is illustrated in Fig. 3B.

None of the rocks examined contains recognizable vitroclastic texture, and there is no evidence that they are tuffaceous.



A B C

Fig. 3.

A.—Arrowsmith Sandstone (specimen Pf2). Clear grains are quartz and stippled grains with cleavage are feldspar. Lithic fragments are volcanic rock (dark) and grains of interlocking quartz. One quartz grain (lower left centre) shows authigenic enlargement, and there are more angular grains than is usual in this field. Cement is fibrous chlorite. Diameter of field 2.4 mm.

B.—Arrino Siltstone (specimen 36916). Clear grains are quartz, stippled grains with cleavage are feldspar and dark grains are volcanic. Fine grains are commonly difficult to identify, but most are quartz. Cement is sparse and forms an iron-stained rim to most grains. Diameter of field 2.4 mm.

C.—Enokurra Sandstone (specimen 38725). Clear grains are quartz, stippled grains with cleavage are feldspar and lined grains are muscovite. Cementation is by enlargement of quartz grains and by clay-sized and sericitic matrix (closely stippled). Diameter of field 2.4 mm.

Environment of Deposition

The Arrino Siltstone was apparently derived from a similar provenance to that of the Arrowsmith Sandstone, but seems to represent a deeper water facies. The same factors that led to preservation of unstable grains in the Arrowsmith Sandstone were presumably operative during deposition of the Arrino Siltstone.

Beaconsfield Conglomerate

The Beaconsfield Conglomerate, which crops out toward the western side of the basin, conformably overlies the Arrino Siltstone, and is made up almost entirely of rounded pebbles and cobbles of volcanic rock. A few pebbles of granitic rock, quartzite and sandstone are also present. The petrology of the Beaconsfield Conglomerate has been described previously (Glover 1958*a*).

The coarseness of the Beaconsfield Conglomerate contrasts with the fineness of the underlying Arrino Siltstone, and its relative homogeneity (mainly volcanic detritus) contrasts with the mixed volcanic, granitic and meta-sedimentary detritus making up the Arrino Siltstone.

Baker (1951, p. 20) thought that the conglomerate was due to increased outpourings of lava combined with penecontemporaneous uplift to the west, and that the boulders were deposited under relatively shallow water conditions. He disagreed with Johnson *et al.* (1954, p. 43) who believed it to be a water-rounded volcanic agglomerate. The present writer agrees with Baker that the Beaconsfield Conglomerate has probably been derived almost entirely from the volcanic cover of an uplifted block. It may have been deposited near the foot of a fault scarp in a shallow marine or even continental environment. However, in view of the petrographic range of the pebbles and boulders (spilites, micro-diorites and volcanic rocks transitional between them), their origin may be less straight-forward than it at first appears.

Enokurra Sandstone

Petrography

The Enokurra Sandstone consists of fine-grained to very coarse-grained sandstone which is locally conglomeratic. It shows well-developed large-scale cross bedding and rests with erosional unconformity on either the Beaconsfield Conglomerate or the Arrino Siltstone (McWhae *et al.* 1958).

Four specimens (Pf1, Pf5, Pf6, 38725) were examined microscopically. The rocks range from feldspathic sandstone to arkose (10-43 per cent feldspar) and three of them contain significant amounts (5-15 per cent) of quartzo-feldspathic lithic fragments. Cement constitutes less than 10 per cent, and the sorting of the grains, which are generally angular, ranges from moderately good to poor.

Specimen 38725 (Fig. 3C), a coarse-grained arkose, with conglomeratic bands, is described below. Its approximate composition by volume is:

	Per cent
Quartz	67
Feldspar	15
Lithic fragments	14
Muscovite, garnet, opaque minerals	2
Clay-sized material, iron oxide	2

The feldspar consists of microcline and of oligoclase replaced partly along cleavages by muscovite. Both varieties of feldspar are somewhat kaolinized, but the oligoclase is generally more strongly altered. Lithic fragments are mainly interlocking quartz with undulose extinction, and some contain microcline, microcline microperthite, muscovite and green-brown biotite. Much of the quartz in these composite grains is traversed by lines of minute inclusions, and commonly contains minute needles of unknown composition, and cracks filled with limonite. The composition of the feldspar, and the mineralogy and texture of the lithic fragments point strongly to their derivation from rocks like the quartz-oligoclase-microcline-biotite gneiss of the Mullingarra Inlier described by Baker (1951, p. 33). Other fragments include myrmekite and muscovitic quartzite. Cementation of the rock is effected partly by muscovite, clay-sized material and limonite, and partly by authigenic quartz outgrowth.

Approximately 10 grams of specimen 38725 were crushed, and 0.3 grams of heavy minerals were present in the grade containing grains with diameters ranging from 0.61-0.125 mm. The heavy minerals consist of ilmenite, generally angular but with a few rounded grains (62 per cent): garnet, weakly magnetic, pale pink and strongly etched, with refractive indices ranging from 1.810-1.815 (31 per cent): apatite, strongly etched (6 per cent): zircon, pale mauve and euhedral, dark brown and rounded (1 per cent): and rare grains of tourmaline and sphene.

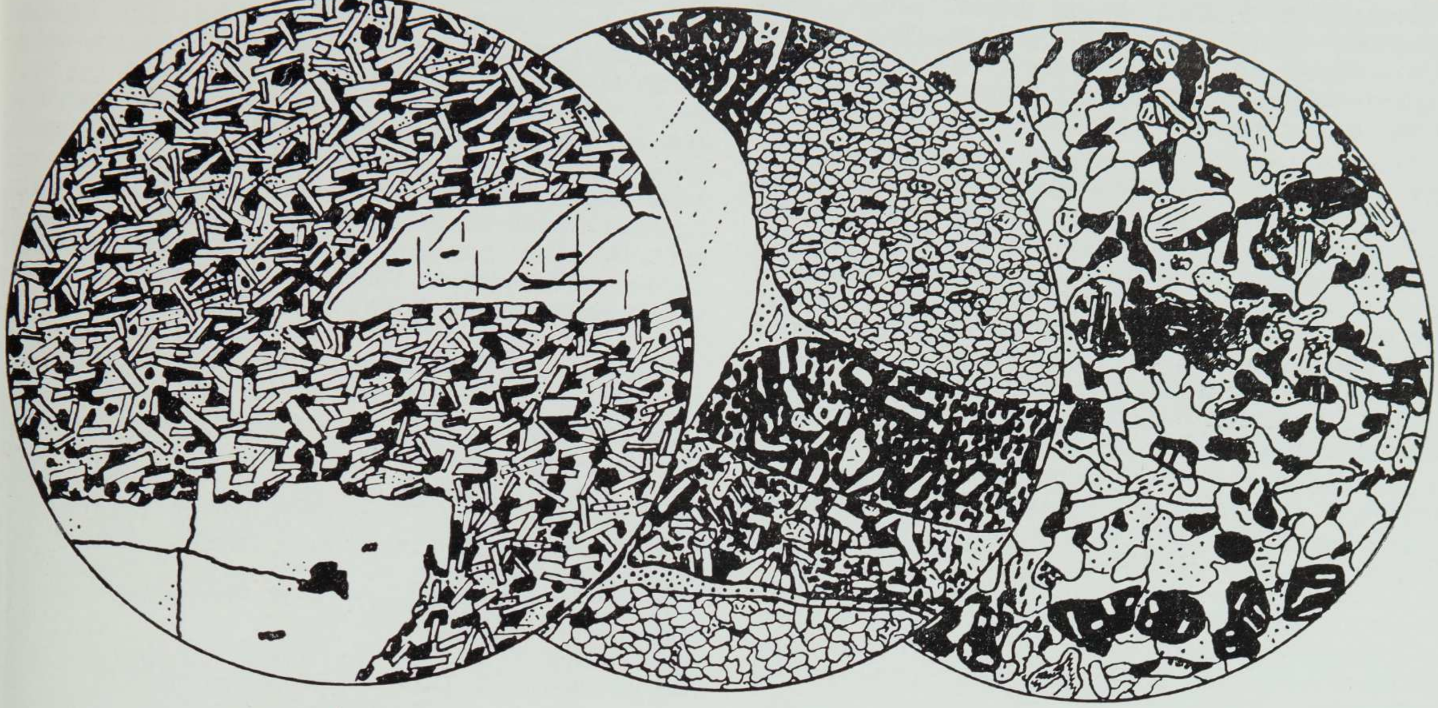
Environment of Deposition

The Enokurra Sandstone is separated from underlying sediments by an unconformity, and differs lithologically from them in containing practically no volcanic material. It was clearly derived therefore, from a different provenance. The abundance of feldspar in the formation shows that chemical weathering was ineffective during erosion and deposition. The generally coarse grain size of the sandstones, and their coarse cross bedding, indicate either shallow marine or continental sedimentation, and the angularity of the sand grains shows the lack of prolonged working. It is likely therefore that the basin, although shallow, was subsiding. The few observations made so far of the cross bedding indicate derivation from the north-west or north-north-west.

Mt. Scratch Siltstone

Petrography

The dominant lithology of this thick formation is siltstone, but abundant shale and some fine- to coarse-grained sandstones occur locally within it, and some conglomeratic lenses were



A B C

Fig. 4.

A.—Pebble of spilitic lava from conglomerate in Mt. Scratch Siltstone (specimen 38705). Partly altered phenocrysts of albite, traversed by ironstained cracks, are set in a matrix of iron ore (black) and chloritized and epidotized sodic plagioclase. Diameter of field 8 mm.

B.—Very coarse-grained lithic sandstone from Mt. Scratch Siltstone (specimen 36921). Fragments include metamorphozed siltstone (top right and bottom), chert (top left) and chloritized and epidotized volcanic rock. The sparse cement (stippled) is a mixture of clay-sized material, quartz and epidote. Diameter of field 2.4 mm.

C.—Very fine-grained sandstone in Mt. Scratch Siltstone (specimen Pf7). Clear grains are quartz, dark grains are volcanic rock, stippled grains are chlorite, dashed grains are epidote. The rock may be partly tuffaceous. Diameter of field 2.4 mm.

encountered. Pebbles and cobbles in the conglomerate are generally well rounded and are red-brown from weathering: 14 of them were examined microscopically, and are classified as follows:

- Micro-porphyritic, chloritized volcanic rock (38705, 38705a, 38708, 38711).
- Sheared epidote-quartz rock (38704, 38710, 38710a).
- Sheared and partly mylonitized feldspathic sandstone (38709, 38711a).
- Granitic gneiss (38703, 38707).
- Feldspathic quartzite (38706).
- Chlorite schist (38708a).
- (?) Hornfels (38709a).

The four pebbles of volcanic rock listed above are of spilitic composition, and one of them (specimen 38705) is briefly described below. It contains plagioclase phenocrysts up to 3 mm long in a groundmass made up of plagioclase laths ranging from 0.3 mm to 0.6 mm in length, black iron ore (mainly magnetite) haematite, limonite and rare patches of quartz. Approximate composition of the rock by volume is:

	Per cent
Plagioclase (phenocrysts)	10
Plagioclase (groundmass)	64
Iron ore	25
Quartz	1

Plagioclase phenocrysts are traversed by red, iron-stained cracks and are altered locally to chlorite, epidote and quartz. Plagioclase laths in the groundmass are more extensively altered, and are generally cloudy. All the feldspar is highly sodic. Cleavage fragments of one phenocryst showed the following indices:

Ng (001) = 1.541 ± .001.
Ng (010) = 1.536 ± .001.
Np = 1.531 ± .001.

Composition (Winchell and Winchell 1956) is therefore close to An_7. Many grains have somewhat patchy extinction, and even where extinction is fairly uniform, measurements with the universal stage show certain optical anomalies.

It is common in sections $\perp a$ for readings of $X' \wedge 010$ to differ considerably in adjacent subindividuals of the same crystal. Thus one crystal showed $X' \wedge 010 = 12°$, $X' \wedge 010 = 17°$ in adjacent lamellae, indicating compositions respectively of An_6 and An_0. These anomalies may be due to an unusual cooling history of the phenocrysts, but no more precise reason for them can be advanced at present.

A coarse-grained lithic sandstone (specimen 36921) from the formation is illustrated in Fig. 4B. It consists of well-sorted, rounded to subangular fragments mostly about 2 mm in diameter, cemented by a sparse fine aggregate of quartz, chlorite, epidote and clay-sized material. About 80 per cent of the grains are of volcanic rock but they are too altered for effective determination. None of the feldspar in them seems more calcic than intermediate andesine and most seems considerably more sodic. Other fragments are fine-grained quartzite, chert, (?) hornfels, chlorite-quartz schist, chlorite-epidote-quartz schist and granitic rock.

Other specimens include siltstone (38712, Pf8, Pf9, Pf10) and very fine-grained sandstone (Pf7). Volcanic fragments make up part of the rocks (13-45 per cent) and other constituents are quartz, plagioclase, epidote, chlorite, muscovite, biotite and minor microcline. Grains are generally angular. Heavy minerals from Pf7 (apart from volcanic fragments) are sparse, and include subrounded to well-rounded apatite, cloudy epidote, colourless, angular, faintly magnetic garnet, biotite and rare pyroxene.

No undoubted vitroclastic texture has been observed in the fine-grained rocks described above, but a few pale brown, weakly anisotropic fragments that probably represent devitrified glass shards are present in them. Moreover, some volcanic fragments have unusual shapes, as though deposited when plastic. These fine-grained rocks are likely therefore to be partly tuffaceous. Unfortunately, fine-grained, water-laid, lithic tuffs and fine-grained sediments derived from erosion of a volcanic landmass are not easily distinguished, even if of fairly recent origin. In neither sediment are grains likely to be rounded, and proof of tuffaceous origin is to be sought in the presence of glass shards, pumiceous fragments and embayed crystal fragments as described by Pirsson (1915). The glass of submarine tuffs may alter rather quickly however (see for example Müller (1958) on Recent sediments in the Bay of Naples), and the features listed by Pirsson tend to become unrecognizable under the influence of compaction and diagenesis in older rocks such as those of the Yandanooka Group. It is clear, however, that much of the material is of normal, epiclastic origin, for it has been derived from granites and meta-sediments. It is also evident that volcanic fragments in the conglomerates and coarse-grained sandstones are epiclastic, for they are rounded, and are associated with rounded fragments of similar size which are not of volcanic origin.

Environment of Deposition

The Mt. Scratch Siltstone is a thick (25,000-30,000 ft.), generally fine-grained sequence derived from a terrain of volcanic, granitic and meta-sedimentary rocks. Volcanism was apparently active during sedimentation: some volcanic material was derived from erosion of the landmass, whereas some was probably blown directly from volcanoes to the basin of deposition and incorporated in the accumulating sediment. The fine-grained rocks probably represent a mixture of epiclastic and pyroclastic deposition.

The general fineness of the formation suggests deeper waters than those prevailing during deposition of the Arrowsmith Sandstone, Beaconsfield Conglomerate and Enokurra Sandstone. Ripple marks have been observed locally by Playford (pers. comm.), but without careful study their value as a criterion of shallow water deposition must be accepted cautiously. Current ripple marks have now been observed on seamounts at depths of over 4,000 feet in recent oceanographical work (Dietz and Menard 1951, p. 2004; Heezen, Thorp and Ewing 1959, p. 59). Small scale cross bedding is a characteristic feature of the formation, but its significance with regard to depth of sedimentation is not understood. The great thickness of the Mt. Scratch Siltstone, and the fact that it is underlain by the shallow marine or continental Enokurra Sandstone shows that subsidence during sedimentation was considerable.

Origin and Deposition of the Yandanooka Group

The Yandanooka Group was derived from a terrain of granitic, meta-sedimentary and volcanic rocks. Most of the sediments are notable for the high proportion of volcanic fragments in them, and they have long been regarded as tuffaceous (Simpson and Glauert in Campbell 1910, p. 97: Woolnough and Somerville 1924: Johnson *et al.* 1954). Baker (1951) however was unable to find evidence of pyroclastic derivation for rocks he examined in the sequence stratigraphically below the Mt. Scratch Siltstone, and evidence cited in this paper supports his conclusions. The possibility that closer sampling of the Arrino Siltstone will reveal tuffaceous bands cannot, of course, be eliminated at present. The Mt. Scratch Siltstone is probably partly tuffaceous in origin. The volcanic fragments are commonly too altered for effective determination for their feldspar is cloudy, and ferromagnesian minerals have been replaced by iron ores and chlorite. Their composition ranges from microdiorite (andesite) to spilitic varieties.

Formations in the Yandanooka Group represent successively, from the base upwards, shallow water, probably littoral faces (Arrowsmith Sandstone); deeper water facies (Arrino Siltstone); shallow water or continental piedmont facies (Beaconsfield Conglomerate); shallow water or continental facies (Enokurra Sandstone); and a thick, fine-grained, partly tuffaceous facies, apparently deposited in fairly deep water (Mt. Scratch Siltstone).

The high proportion of labile constituents, such as feldspar and volcanic fragments, shows that the processes of mechanical disintegration dominated over those of chemical decay. The tectonic environment that best explains the petrography of this thick sequence is that of a sporadically subsiding basin bounded by a fairly rugged land surface. Some of the volcanism, at least, was contemporaneous with sedimentation.

The Enokurra Sandstone, unlike formations below and above it, contains no volcanic detritus. It was eroded from a granitic and meta-sedimentary provenance, and presumably came from a different direction from that of the other sediments. Its distinctive lithology, and the unconformity at its base, are best explained by sudden tectonism.

The areas from which the Yandanooka sediments were derived are not yet known. The nearest volcanic rocks are east of the Darling Fault near the Billeranga Hills, where intrusives lithologically like the microdiorite pebbles of the Beaconsfield Conglomerate have been mapped by Arriens and Lalor (1959). Their careful work has failed, however, to reveal spilitic rocks, although it is possible that they may eventually be found in the network of altered intrusions near the Darling Fault not investigated by them. They have mapped trachytes whose mineralogy was briefly discussed earlier (Glover 1958*b*), but no representatives of these distinctive rocks have been encountered in the Yandanooka Group. Abundant chert fragments would also be expected in the group if it had been derived from the sequence at present exposed in and near the Billeranga Hills, for considerable thicknesses of this resistant rock were found by Arriens and Lalor. If the volcanic detritus of the Yandanooka Group came from the east, it was presumably eroded from rocks that blanketed and concealed the present sequence. The Enokurra Sandstone, on the other hand, was derived from rocks very like those now exposed in the Mullingarra Inlier, and this is consistent with the evidence from cross bedding, which suggests a source to the north-west or north-north-west.

In view of the great thickness of sediments (about 30,000 feet of which remain) and the high proportion of volcanic material in most of them, extrusion must have been on a very large scale. It is conceivable that downwarping occurred partly as isostatic readjustment in response to the outpourings. The presence in the area of large faults (including the Darling Fault and the Urella Fault) is consistent with the tectonic picture suggested. There is, however, no undoubted evidence for their existence at the time of deposition of the group.

The Arrino Siltstone and Mt. Scratch Siltstone are notable for their red-brown to purplish colour in the field. There is no evidence at present to suggest that these formations are "Red Beds" in the normally accepted geological sense, and their deep colouration is believed due to surface oxidation (weathering) of their iron-rich, volcanically derived material. Examination of well cores or cuttings, however, would be necessary to demonstrate this.

Acknowledgments

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